STUDY OF JOSHI-EFFECT IN IODINE VAPOUR IN THE PRESENCE OF POWDERED IODINE UNDER ELECTRICAL DISCHARGE*

INFLUENCE OF DIFFERENT DETECTORS

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(*Received for publication, June 12, 1948*)

ABSTRACT. Joshi-effect Δi in iodine is studied in an ozoniser discharge of 50 cycles frequency in the potential range $0.5-2$ kV (r. m. s.), the annular space being filled with powdered iodine. Current i was measured with a serially connected vacuo-junction and an oxide rectifier with an inductively and resistively coupled diode, triode and pentode. The 'threshold potential' V_m (*viz*, 0.95 kV) was independent of the nature of any of the above detectors; for each of these, the relative Joshi-effect $-\%\Delta i$, *i. e.* $\frac{-\Delta i \times 100}{i_D}$ where i_D is the current in dark is maximum near V_m. The observed dimunition (numerically) in $-\%\Delta i$ with resistive impedances in the low tension line is attributed to the preferential damping of the H. F. components of i which are found by Joshi to be the chief seat of this phenomenon. The first positive effect $+\Delta i$ has been observed at low applied V with all the detectors. A second positive effect is also observed under heavy resistive inputs with triode and pentode. Based on Joshi's result, that the second positive effect is associated with the H.F's in the grid circuit and that it can be eliminated by (1) shifting the grid bias to higher negative values, (2) by-pass grid capacity, evidence has been adduced to show that this is associated with the external detector circuit; is due to a shift of the grid voltage towards positive by a decrease of the grid current, under irradiation.

INTRODUCTION

Two general results of significance to the elucidation of the above phenomenon, (an instanteneous and reversible photo-variation, usually though not invariably dimunition of the discharge current $-\Delta i$,) have been emphasized by Joshi ; (1) The magnitude of Δi is affected markedly by the nature of the excited solid-gas interface (Joshi, 1943, 1945*c*, 1947 ; Cherian, 1945) ; and (2) Of the operative conditions, specially the detector employed (Joshi, 1943, 1945*a*). The present work report result for the Joshi-effect in iodine, excited by an ozoniser discharge under a large surface influence by the introduction of powdered iodine in the discharge space and using a series of current indicators.

EXPERIMENTAL

The general experimental arrangement and the circuit employed are shown in Fig. 1. Alternating potentials of 50 cycles frequency obtained from a rotary

* Communicated by Dr. S. S. Joshi.

converter worked off 220 volt D.C. mains were applied to a Siemens' glass ozoniser; its annular space was filled with powdered iodine. The deflections of the galvanometer (G) were noted at each applied kV in dark (i_D) and under irradiation (i_L) from a 220 volt, 200 watt incandescent (glass) bulb by manipulating with a shutter, under the following detecting arrangements :

(*a*) The low tension electrode was earthed through an appropriately shunted vacuo-junction connected to a reflection galvanometer.

(*b*) The current i passed through a metal oxide rectifier and a serial galvanometer.

(*c*) A double diode (83 V) was used as a half-wave rectifier. i was admitted to (1 : 10) Bell transformer ; its secondaries were connected to the plates and the filament through the galvanometer. The input was next tapped from a non-inductive and practically non-capacitative Dubilier resistance R, varied in the range 2-25 kΩ.

(*d*) Triode (37) was used as an anode bend rectifier in place of the diode used in (*c*). The secondaries of the Bell transformer were connected to the grid and the cathode through a grid bias battery. As in (*c*) the input was also tapped from R, varied from 50-500 kΩ.

(*e*) Pentode (6J7) was used as an anode bend rectifier. The input taken first from the secondaries of the transformer and then across R, varied from 50-500 kΩ, was applied between the control grid and the cathode.

Results of a typical group of experiments made with each of these detectors, for i_D, i_L ; the net Joshi-effect $i_D \sim i_L = \Delta i$; its relative value $\frac{100 \times \Delta i}{i_D} = \% \Delta i$ are returned in Table I.

DISCUSSION

During this work the basic significance of the 'threshold potential' V_m (Joshi, 1929, 1939, 1945*d*, 1946*b*) as located by observation of an initial rapid increase of i with V was noticed. Despite the widely divergent modes of i measurement (*a* to *e*, Fig. I) V_m for the iodine tube used in this work was fairly constant, *viz.*, 0.95 kv. Well below V_m the conductivity is entirely capacitative (Joshi, 1945*d*) and even intense and short wave irradiations do not produce Δi. Joshi considers that the breakdown of the gas sets in at and even (just) less than V_m Like Paschen potential V_m is a simple linear function of the gas pressure (Joshi, 1946*b*) and as suggested by Joshi, it is extremely likely that the 'electron affinity' of the excited gas (Joshi, 1939, 1946*b*) besides its ionisation potential is a chief determinant thereof. In general it is found that the discharge current i (as also the velocity of any associated change) depends principally on V-V_m. The effect of light is to increase V_m (Joshi, 1939, Joshi and Narsimhar, 1940, 1945*d*). From this Joshi predicted and actually observed a current decrease $-\Delta i$, a consequence at variance with the current theories of photoelectric and discharge reactions.

With all the above modes of detection (*a* to *e*, Fig. 1) a positive Joshi-effect has been observed at low potentials, and the negative Joshi-effect at

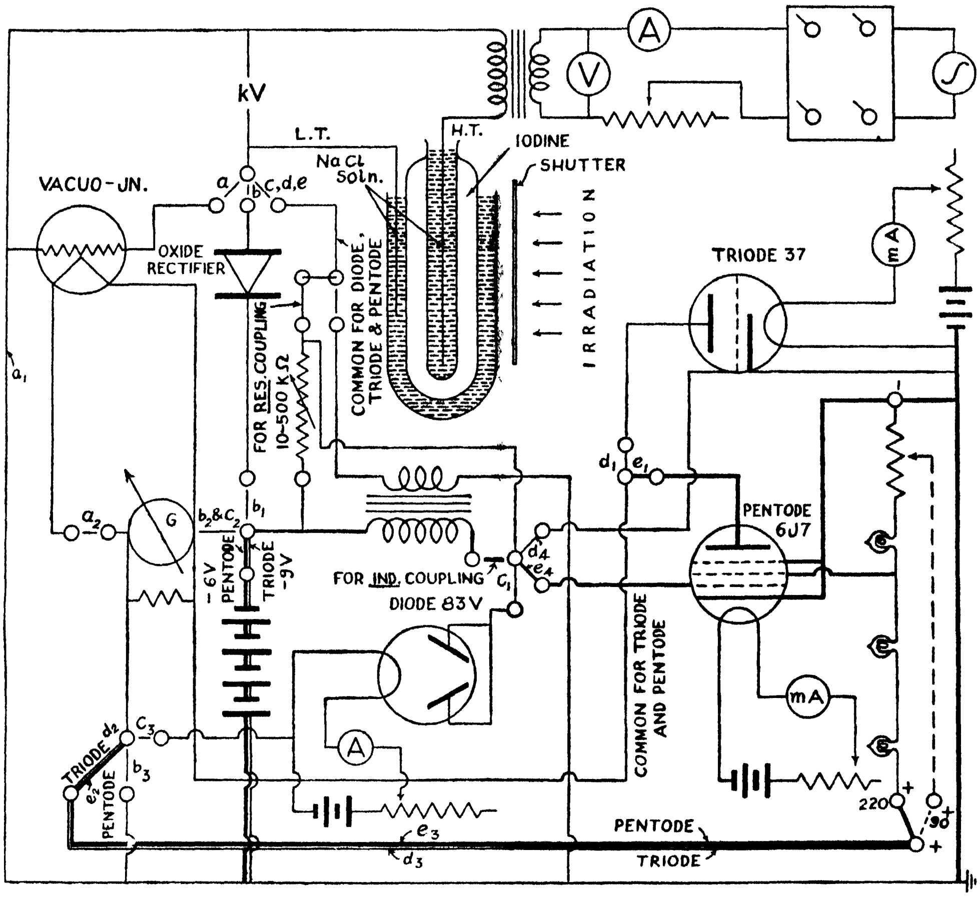

FIG. 1

higher potentials. The transition from the positive to the negative Joshi-effect was found to be repeatedly and reproducibly potential reversible (Joshi, 1943, 1947). A positive Joshi-effect $+\Delta i$ has been observed by Joshi (1943, 1945*c*, 1947) (*i*) in numerous cases under special coating materials on the annular walls *e.g.*, with KI_3 + KI mixture, vapours of iodine, phosphorus and sulphur; (*ii*) spontaneously after a long 'ageing' at a constant *V* in a semi-ozoniser excitation; and (*iii*) in chlorine under H.F. discharge and also low frequency excitation under increased relative surface by introducing powdered wall material in the discharge space and had generalised that, *inter alia*, a low applied *V* favours $+\Delta i$ Joshi, 1947). The positive effect being shown by all the indicators used in this work suggests that it corresponds to a distinctive photo-reaction under discharge. It is found (unpublished results of Joshi) that V_m decreases under irradiation corresponding to the production of this positive effect as is to be expected from the general result for the dependence of i on $V\text{-}V_m$. As the exciting potential is increased the positive effect diminishes rapidly. Above V_m over a fairly wide range, the negative Joshi-effect occurs. The limited range of conditions within which only positive effect is observed corresponds perhaps to the comparative rarity of the positive ion emission (Joshi, 1947). A positive Joshi-effect is, however, to be anticipated from the greater probability of the photo-ionisation of the pre-excited particles (Joshi, 1947) under the discharge.

The results in Table I, show that the nature of the detector used affects appreciably the magnitude of the corresponding negative and positive Joshi-effects. Thus, *e g.*, the -%Δi indicated by the vacuo-junction was 25 at 1.1 kV whereas the oxide rectifier showed a maximum of 33 %. This is significant since the input current was the same. From his oscillographic studies of the Δi phenomenon, Joshi (1943*a*, 1944, 1944*c*, 1945*d*) has shown that "the current i contains a large number of frequencies of varying strengths" (in addition to the supply frequency and its harmonics)—"the vacuo-junction has a low capacity and a negligible inductance, a stable characteristic over a wide range of applied V and frequency of A.C. supply (Joshi, 1945*e*)". The oxide rectifier on the other hand is a more selective and variable detector (Khastagir, 1934-35). The numerically greater -%Δi, as observed, may, therefore, be attributed to its preferential response to some of the frequencies constituting the discharge current.

Comparing all the detectors in respect of i_D, i_L, $-\Delta i$ and $-\%\Delta i$, it is seen (Table I) that the results obtained with oxide-rectifier, vacuo-junction and diode as detectors are substantially similar. Thus whilst $-\%\Delta i$, which is maximum near V_m but decreases (numerically) thereafter, $-\Delta i$ attains a maximum and then decreases (numerically), i_D and i_L increase progressively. Furthermore, the relative variation in $-\Delta i$ was markedly pronounced with the diode for the same increase in V, *e g.*, $-\Delta i$ and $-\%\Delta i$ were respectively (42, 38) at 0.83 kV; (35, 15) at 1.36 kV; and zero at 1.77 kV and at larger V. The results with triode and pentode form apparently a separate group, *e.g.*, $-\Delta i$ and $-\%\Delta i$ attain a maximum near V_m and then decrease (numerically) with V. In the case of resistive coupling, however, the curve $i_D - V$ saturates at higher V and lies below $i_L - V$ curve.

It was significant to observe that the magnitude of both $-\Delta i$ and $-\%\Delta i$ with the inductive coupling of the detector diode was higher than when the input was tapped across a non-inductive and practically non-capacitative Dubilier resistance R (Fig. 2); thus, *e.g.*, at $R = 10\ \mathrm{k}\ \Omega$ the maximum $-\%\Delta i$ is only 13 at 0.95 kV whereas the inductive coupling records a maximum of -38 at 0.82 kV. The influence of R in suppressing $-\%\Delta i$ was markedly uniform under all conditions of excitation. A like inhibition of the negative Joshi-effect was observed by resistive impedances in the case of triode and pentode, where it was further observed that a transition from a negative to an apparently second positive effect occurred as the (resistive) input exceeded a certain critical value. Thus, *e.g.*, using triode as the current detector and at R = 300 kΩ., $\%\Delta i$ changed from -5 to $+18$ as the applied potential increased from 1.09 to 1.90 kV. It must be emphasized, however, that the grid current always showed a higher negative effect.

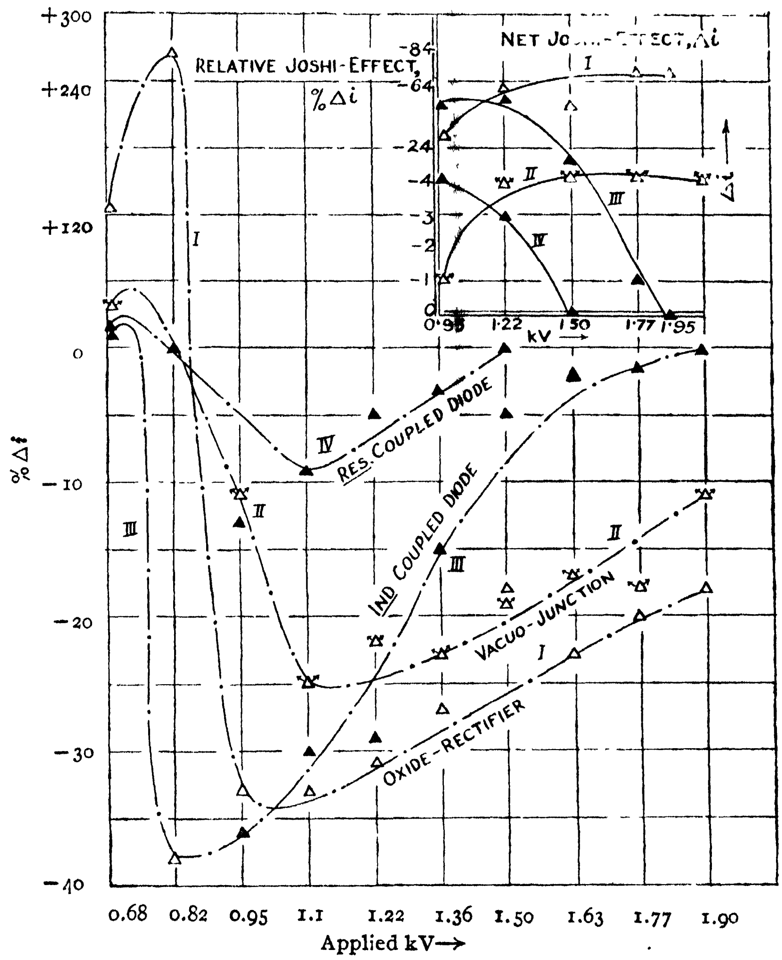

FIG. 2

That $-\%\Delta i$ should be least where the detector was coupled resistively follows from Joshi's theory (Joshi, 1945*e*). Evidence was adduced previously that the Joshi-effect is caused by a decrease of the amplitudes of H.F. components of i. That R acts likewise, that is, mainly damps the H.F. appeared from the oscillograms of i under various R's; this also follows from the general considerations of an oscillatory discharge of a condenser (such as an ozoniser) in a resistive circuit (Joshi, 1945*e*). The damping constant of an oscillatory circuit consisting of R, the inductance L and capacity C is given by $R/2L$; the skin-effect arises from the uneven radial distribution of current in a conductor. Thus it is obvious that in the inductive coupling the magnitude of $-\%\Delta i$ would be largest due to low (ohmic) resistance in the oscillatory circuit. On the other hand with the valves coupled resistively and in the vacuo-junction and oxide rectifier an appreciable resistance is introduced; this increases the damping and also the skin effect, as a consequence a reduction of H.F. oscillations occurs prior to irradiation and therefore, in the corresponding magnitude of $-\%\Delta i$.

Unlike the first, the second positive effect does not originate from a distinctive physical change under the discharge but is associated with the external detector circuit in grid controlled detectors. It is instructive to consider the following factors in regard to the production of the second positive effect at large resistive inputs. The anode current depends on the grid

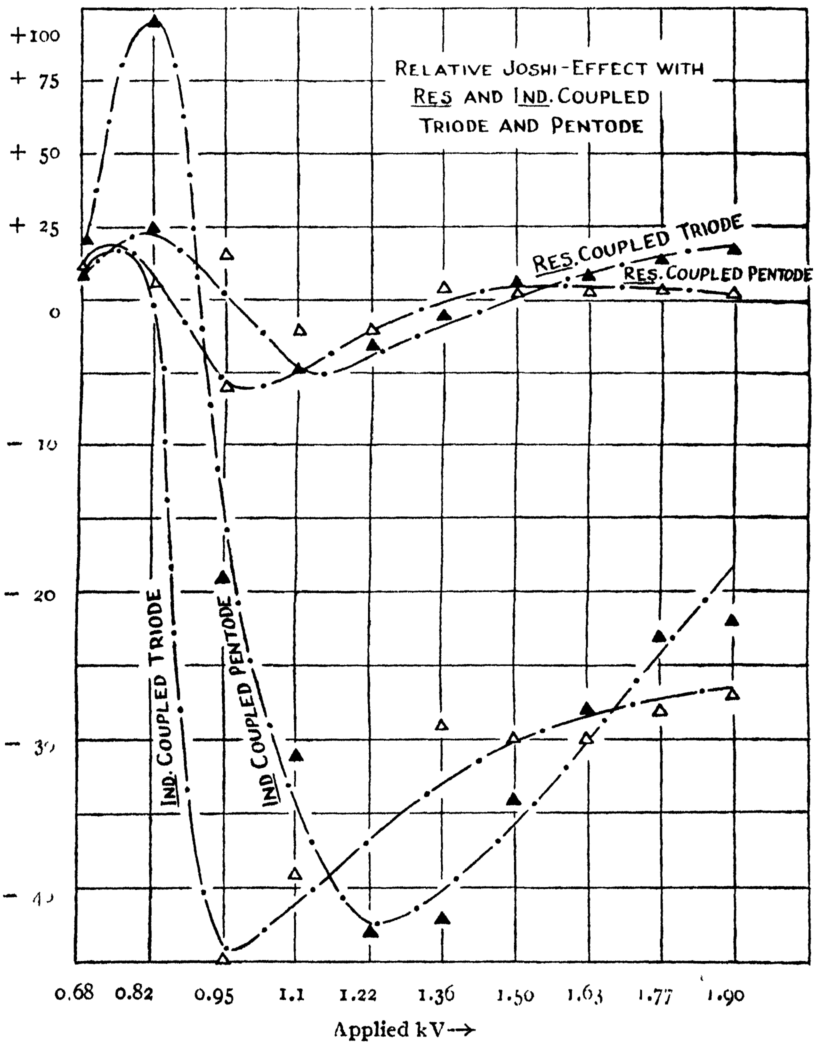

FIG. 3

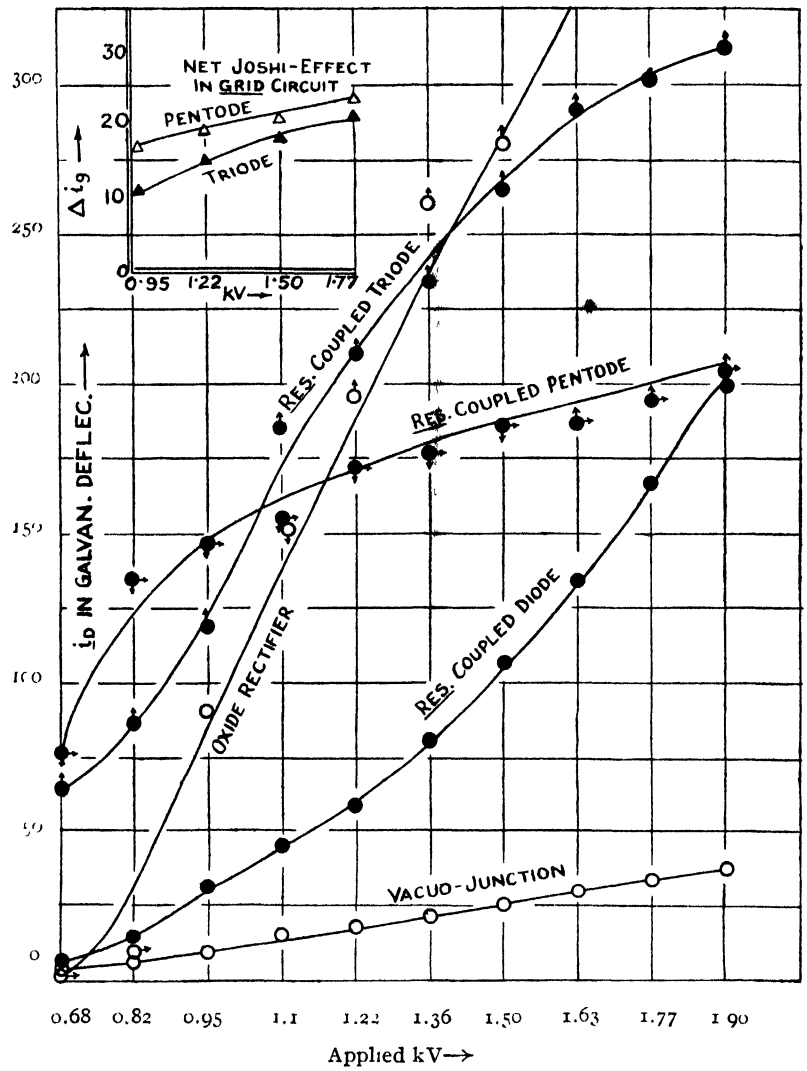

FIG. 4

Current i_D with different detectors

voltage at a constant plate potential; ordinarily in a valve biased for the anode bend rectification, the anode current varies correspondingly with grid voltage. This holds strictly only in the case of weak signals. When, however, a high impedance is present in the grid circuit and the signal strong (as in the inputs studied in this work) a flow of grid current causes an amplitude distortion during positive half of the cycle. If the above impedance (R_g) be purely resistive and i_g the grid current, the grid will be held negative by an additional amount ($R_g \times i_g$). That this grid shift affects the anode current appreciably is brought out by the characteristic potential-current curves (Fig. 4) where i_D shows a markedly greater increase with low, than

TABLE I

Potential Variation of the Joshi-effect in Iodine (Discharge space packed with powdered iodine)

↓Applied kV (rms)	Detector used coupled with L. T.	Oxide rectifier	Vacuo-junction	Double diode 83V Inductively	Double diode 83V Resistively	Triode 37 Inductively	Triode 37 Resistively	Pentode 6J7 Inductively	Pentode 6J7 Resistively
0.68	i_D	4	3	25	6	40	64	110	77
	i_L	9	4	29	7	48	70	126	100
	Δi	+ 5	+ 1	+ 4	+ 1	+ 8	+ 6	+ 10	+ 23
	$\% \Delta i$	+125	+33	+ 16	+ 17	+ 20	+ 9	+ 9	+ 30
0.82	i_D	8	6	110	14	55	87	128	134
	i_L	29	6	68	14	108	109	137	120
	Δi	+ 21	—	− 42	—	+ 53	+ 22	+ 9	− 14
	$\% \Delta i$	+263	—	− 38	—	+ 96	+ 25	+ 7	− 10
0.95	i_D	90	9	137	32	210	118	288	146
	i_L	60	8	88	28	170	137	158	137
	Δi	− 30	− 1	− 49	− 4	− 40	+ 19	−130	− 9
	$\% \Delta i$	− 33	−11	− 36	− 13	− 19	+ 16	− 45	− 6
1.1	i_D	153	16	162	45	310	185	305	155
	i_L	103	12	114	41	215	176	186	152
	Δi	− 50	− 4	− 48	− 4	− 95	− 9	−119	− 3
	$\% \Delta i$	− 33	−25	− 30	− 9	− 31	− 5	− 39	− 2
1.22	i_D	196	18	197	58	405	210	300	172
	i_L	135	14	140	55	230	204	220	169
	Δi	− 61	− 4	− 57	− 3	−175	− 6	− 80	− 3
	$\% \Delta i$	− 31	−22	− 29	− 5	− 43	− 3	− 27	− 2

TABLE I (*contd.*)

Potential Variation of the Joshi-effect in Iodine (Discharge space packed with powdered iodine)

↓Applied kV (rms)	Detector used coupled with L. T.	Oxide rectifier	Vacuo-junction	Double diode 83V		Triode 37		Pentode 6J7	
				Inductively	Resistively	Inductively	Resistively	Inductively	Resistively
1.36	i_D	259	22	240	80	420	226	323	177
	i_L	190	17	205	78	245	224	230	182
	Δi	− 69	− 5	− 35	− 2	−175	− 2	− 93	+ 5
	$\% \Delta i$	− 27	−23	− 15	− 3	− 42	− 1	− 29	+ 3
1.50	i_D	276	26	267	106	425	235	342	186
	i_L	226	21	253	106	281	250	241	191
	Δi	− 50	− 5	− 14	—	−144	+ 15	−101	+ 5
	$\% \Delta i$	− 18	−19	− 5	—	− 34	+ 6	− 30	+ 3
1.63	i_D	335	30	280	134	425	265	360	187
	i_L	257	25	275	134	308	287	251	192
	Δi	− 78	− 5	− 5	—	−117	+ 22	−109	+ 5
	$\% \Delta i$	− 23	−17	− 2	—	− 28	+ 8	− 30	+ 3
1.77	i_D	356	34	320	166	427	292	363	195
	i_L	286	28	319	166	327	332	263	201
	Δi	− 70	− 6	− 1	—	−100	+ 40	−100	+ 6
	$\% \Delta i$	− 20	−18	—	—	− 23	+ 14	− 28	+ 3
1.90	i_D	393	37	350	200	430	326	373	204
	i_L	323	33	350	200	337	386	273	207
	Δi	− 70	− 4	—	—	− 93	+ 60	−100	+ 3
	$\% \Delta i$	− 18	−11	—	—	− 22	+ 18	− 27	+ 1

at larger V; thus, *e.g.*, with resistively coupled pentode it increased from 77 to 177 as V increased from 0.68 to 1.36 kV whereas it increased only from 177 to 204 with further increase from 1.36 kV to 1.90 kV. The resistively coupled diode, however, increased from 6 to 80 and 80 to 200 over the same range. This differential behaviour of the anode current is due to its suppression by the extra negativity of the grid bias. From his oscillographic studies of the Δi phenomenon Joshi has shown that the input across a resistance consists of a low amplitude L.F. and large amplitude H.F. It follows from above that the grid current is mainly derived from H.F. parts of i. On irradiation, however, the H.F's. are chiefly suppressed and the grid current is reduced. This is equivalent to a grid shift towards positive by $(\Delta i_g \times R_g)$, where $-\Delta i_g$ is the net Joshi-effect in the gird circuit. The resultant anode current i_L will depend on the magnitudes of: (i) the diminution of the signal strength and (ii) the positive grid shift. The observations in the grid circuit (Fig. 4) show that the net Joshi-effect $-\Delta i_g$ increases (numerically) with V (Fig. 4). The other detectors, *viz.*, diode and vacuo-junction, however, show that the net Joshi-effect $-\Delta i$ which measures the total amplitude diminution, attains a maximum near V_m and decreases (numerically) thereafter (Fig. 2). Thus for a given R and large V the positive influence on the anode current of the grid shift exceeds the suppression of the anode current by the decrease under light of the signal strength ; a positive effect should therefore, result as observed. Joshi observed that the second positive effect disappears on increasing (numerically) the grid bias, and that higher the operating voltage, the greater is the increase necessary for the above purpose. This is in accord with the above considerations. That the second positive effect is associated with the H.F's. in the grid circuit was inferred by Joshi in a general result (unpublished) that the introduction of a by-pass grid capacity eliminates it.

ACKNOWLEDGMENT

My grateful and sincerest thanks are due to Prof. S. S. Joshi, D.Sc. for having suggested the problem, and for his valuable guidance and keen interest during the course of this work.

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